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U1S S1637

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EP 0676622 A1	**EP 0605847 A1**	**WO 95/02807 A1**
US 5619133 A	**US 4862396 A**	**US 4710709 A**

(58) Field of Search
UK CL (Edition Q) **G1N NACNA NACNC NACND NACNE NAEB NAEM NAFA**
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(54) Abstract Title
Displacement measurement

(57) A displacement detecting device 1 comprises an elongate reference means 2, an electromagnetic signal generator 34, and a transmitting/receiving means which transmits the electromagnetic signal to the reference means 2. The means 31 receives the electromagnetic signal, which is modulated by displacement of the reference means 2. Such modulation provides information as to the amount of such displacement. Signal processing means 35 receives the signal and derives therefrom the relative displacement of the reference means 2 and means 31. The signal generator 34, transmitting and receiving means 31 and signal processing means 35 are all mounted in a common housing 32. Such an arrangement allows for a direct readout of displacement data on displays 37, 38 which are also mounted in the common housing 32, without the need for connection to separate, special purpose control and readout devices. An output signal in standard format (eg a TTL quadrature signal) may be provided via a flying lead 40, for connection to standard readout and/or control instrumentation (e.g. a standard numerical display, CNC controller, etc.)

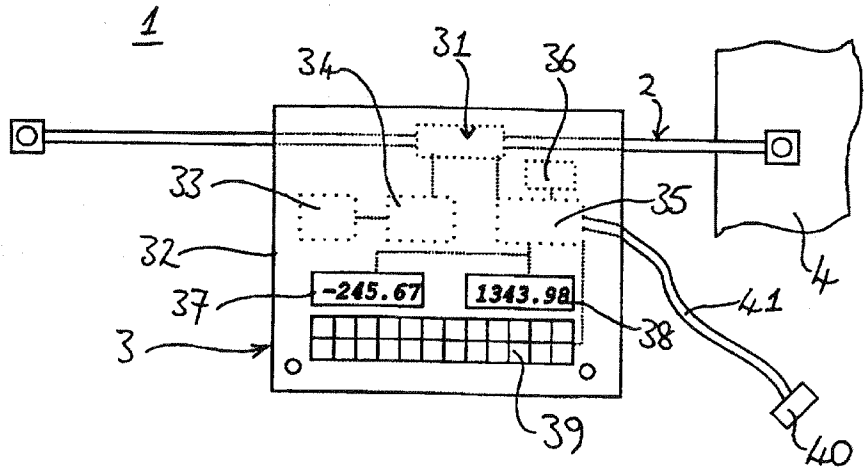

FIG. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1995

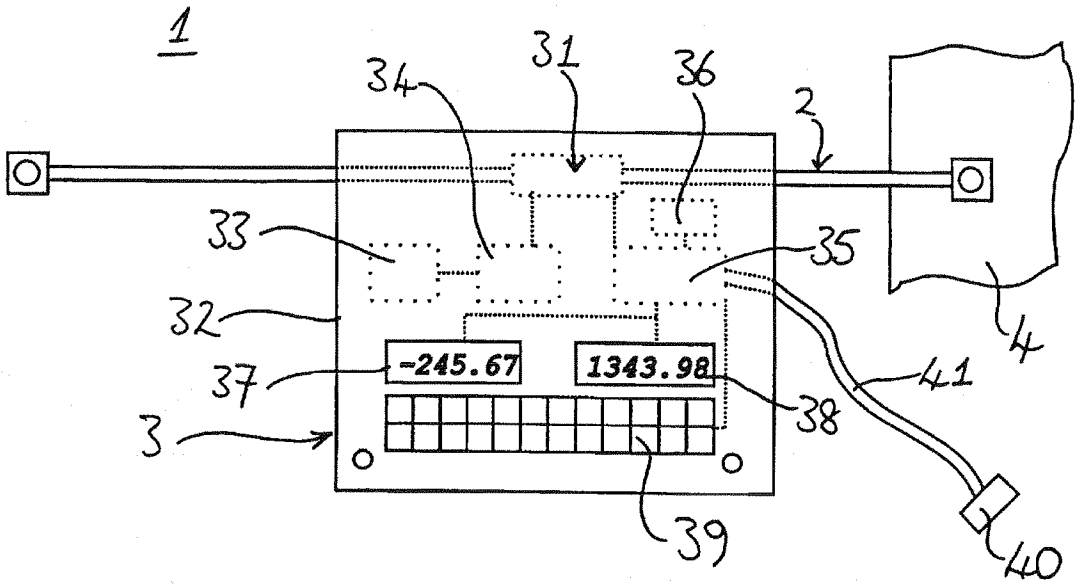

FIG. 1

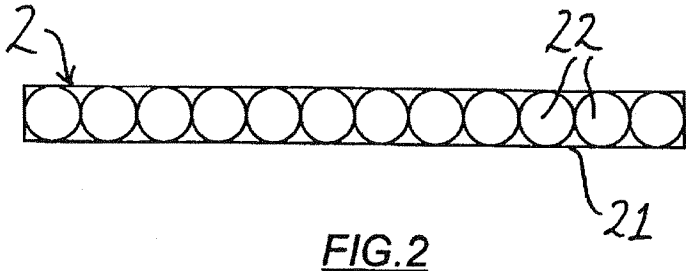

FIG.2

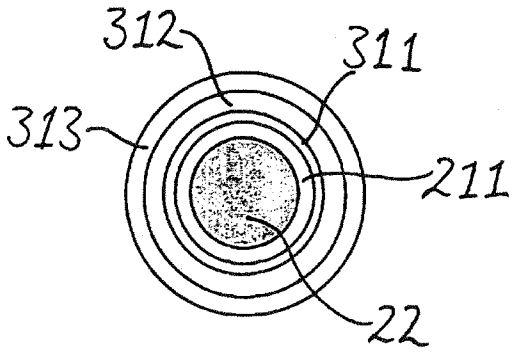

FIG.3

DISPLACEMENT MEASUREMENT

This invention relates to position or displacement detectors for measuring relative movements.

Position displacement detectors are widely used, especially in relation to their application and use on machine tools.

One such known position detector operates on the principle of two glass diffraction scales sliding relative to one another. Each of the glass diffraction scales has formed upon its surface accurately etched parallel lines. As one glass scale is displaced relative to the other glass scale, dark fringes are created when the two etched patterns are superimposed on each other. These dark fringes, known as Moiré fringes, appear and disappear as one glass scale is displaced relative to the other glass scale. This periodic appearance and disappearance of the Moiré fringes may be counted by means of passing a light source through both of the glass diffraction scales and measuring each occurrence of each Moiré fringe by means of a photo-electric cell placed adjacent to the surface of one glass scale and directly opposite to the light source behind the other glass scale. This recording of the Moiré fringe may be then suitably processed and the resultant signal displayed on a readout panel in a digital form, or further suitably processed for use by a computer numerically controlled machine tool.

Such known displacement detectors have further been improved by making the reverse side of one of the glass scales a mirrored surface so that the light source and the photo-electric cell may be conveniently placed, together with a short length of glass diffraction scale, in one combined unit.

This method allows for the easy installation of such known displacement detectors on machine tools and other machines where distances have to be measured accurately. An advantage of this known method is that virtually any length of glass diffraction scale may be produced by abutting the end linear edges of shorter accurately manufactured glass diffraction scales.

A problem with such known displacement detectors, however, occurs when they are used in practice, and particular, when they are used on machine tools.

Machine tools during cutting operations generate large amounts of swarf, and additionally, usually operate in a dirty environment comprising a mixture of oils, water and various cutting fluids. These liquids easily find their way, despite the sealing and cleaning means provided by the displacement position manufacturers, onto the glass diffraction scales, thus interfering with the effective transmission of the light beam, and as a consequence, may cause the displacement detector to stop working, or yet worse, to give erroneous readings.

In British Patent 1 513 567 (expired) another method is disclosed for the measurement of displacement. In this known method a plurality of spherical identical balls made of a magnetic material are enclosed side by side, and in point contact, in a row formation in a tube of non-magnetic material. A combined transmitter coil and receiver coil, a known linear distance apart relative to each other, are placed co-axially around the said tube. A periodically varying magnetic field is produced in the balls by the transmitter. This magnetic field produced in the balls is received by the receiver coil. As the transmitter and receiver coils are moved, relative to the

balls, a phase shift of the periodically varying magnetic field is caused by the said relative movement. The degree of phase shift is measured, the signal processed, and the resultant signal displayed digitally on a readout.

This known method overcomes the problem suffered by the aforesaid glass diffraction scales which can become dirty in use. In fact, this known method is able to work effectively even when actually totally submersed in oils and other liquids. One problem with such a known method is, however, that special signal processing circuitry is required externally of the measurement device, and that direct readout signals to conventional display or control equipment are not readily available from the measurement advice. The known device is not readily portable.

Preferred embodiments of the present invention aim to provide displacement and/or position detectors and methods of using the same that may be improved in the foregoing and other respects.

According to one aspect of the present invention there is provided a displacement detecting device comprising:

a. an elongate reference means;

b. a signal generator arranged to generate an electromagnetic signal;

c. a transmitting means arranged to transmit said electromagnetic signal to said reference means;

d. a receiving means arranged to receive said signal, the arrangement being such that displacement of said reference means relative to said transmitting and receiving means modulates said signal as received by said receiving means, such

modulation providing information as to the amount of such displacement;

e. signal processing means arranged to receive said signal from said receiving means and derive therefrom measurement information indicating the relative displacement of said reference means and body; and

f. a common housing in which said signal generator, transmitting means, receiving means and signal processing means are mounted.

Preferably, said measurement information is represented by a TTL quadrature signal that is output by said signal processing means.

Preferably, said body provides a recess or aperture for mounting or passage of said reference means to provide sliding movement between said body and said reference means.

Preferably, said reference means comprises at least one tube containing a plurality of spheres.

Preferably, said transmitting and/or receiving means comprises a respective coil.

According to another aspect of the present invention, there is provided a method of measuring the displacement of two parts relative to one another, comprising the steps of:

g. fitting to one of said parts the reference means of a displacement detecting device according to any of the preceding aspects of the invention;

h. fitting to the other of said parts the transmitting and receiving means of the displacement detecting device;

i. transmitting said electromagnetic signal to said reference means by the transmitting means of the displacement detecting device as said parts are moved relative to one another;

j. receiving said signal by the receiving means of the displacement detecting device as said parts are moved relative to one another, with the displacement of said reference means relative to said transmitting and receiving means modulating said signal as received by said receiving means; and

k. processing the modulated signal received by said receiving means to derive from the modulation of the signal information as to the amount of the displacement of said reference means relative to said transmitting and receiving means and therefore the amount of the corresponding displacement of said two parts relative to one another.

According to a further aspect of the present invention, there is provided a machine tool fitted with a displacement detecting device or adapted to perform a method according to any of the preceding aspects of the invention, in which the displacement detecting device is arranged to output a signal providing information as to the amount of relative displacement of two moving parts of the machine tool.

Such a machine tool may be a CNC machine.

For a better understanding of the invention, and to show how embodiments of the same may be carried into effect, reference will now be made, by way of example, to the accompanying diagrammatic drawings, in which:

Figure 1 shows one example of a measurement system embodying the invention;

Figure 2 shows one example of an elongate reference means of the system of Figure 1; and

Figure 3 shows one example of the reference means of Figure 2, with transmitting and receiving coils.

The measurement system 1 of Figure 1 comprises an elongate reference means 2 which is affixed to a first part of a machine and a measurement unit 3 which is fixed to a second part of the machine. The first and second parts of the machine 4 are moveable with respect to one another such that the elongate reference means 2 slides within the measurement unit 3 with relative movement of the first and second machine parts.

One example of the elongate reference means 2 is shown in Figure 2. It comprises a tube 21 in which a series of high precision metal balls 22 are disposed in close abutting side by side relationship, the balls 22 being of a ferromagnetic material. The tube 21 may be of stainless steel or any other

suitable non-magnetic material - modern composite materials being particularly suitable for strength.

The measurement unit 3 comprises a coil assembly 31 through which the elongate reference means 2 passes. The coil assembly 31 is located within a housing 32 of the measurement unit 3.

Also located within the same housing 32 are a power supply 33, a wave generator 34, a signal processor 35, a non-volatile memory 36, a first display 37, a second display 38 and a keyboard 39. A signal connector 40 is connected to the signal processor 35 by a flying lead 41. If desired, an electrical connector or port may be provided on the housing 32 to connect with an adjacent end of the flying lead 41.

In use, the power supply 33 supplies power to all components of the measurement unit 3. The wave generator 34 generates an electromagnetic signal of periodic waveform which is supplied to one or more transmitting coil of the coil assembly 31. The signal thus transmitted is picked up by one or more receiving coil in the coil assembly 31, and the output of the or each receiving coil 31 is fed to the signal processor 35. When there is relative movement between the fixed reference means 2 and the measurement unit 3, the signal as transmitted by the or each transmitting coil is modulated by the balls 22 moving through the magnetic field, and the modulated signal is picked up by the or each receiving coil. The modulation is then detected by the signal processing means 35, and provides an indication of the relative displacement of the reference means 2 and the measurement unit 3.

Position detectors that operate generally on the above described principle have been known for many years and, for example, reference is made to the above-mentioned British Patent 1 513 567. For example, in that specification, it is suggested that the waveform applied to the transmitting coils may be sinusoidal, and measurement distance may be deduced from phase measurement. Although the use of a sinusoidal waveform is convenient, the use of any other known waveform is possible, and comparison of the received, modulated signal with the transmitted signal by modern signal processing techniques is relatively straightforward.

By the same token, although the use of high precision steel balls 22 with a tube 21 is a convenient way of providing an elongate reference means 2, in principle any body in which the density of magnetic material varies along its length may be utilised, different shapes and configurations giving rise to different modulation patterns, all of which can be discriminated and detected, since the patterns are predetermined and known.

The output from the signal processor 35 is fed to the two displays 37 and 38. The first display 37 shows relative movement of the reference means 2 and measurement unit 3 during a current movement and/or subsequent to a last reset. The second display 38 shows the absolute position of the measurement unit 3 relative to the reference means 2.

Operation of the system may be controlled via the keyboard 39, which may also be used to enter data such as a present absolute position, reset to zero, etc.

Since all of the components of measurement unit 3 are contained within the housing 32, the measurement system 1 may be constructed as a self-contained unit, which may be portable and/or suitable for retro-fitting to an existing machine. Here, the word "machine" is used conveniently to denote any apparatus which has two relatively moving parts.

The signal processor 35 also provides via the flying lead 41 and connector 40 a signal which may be used to drive directly a standard numerical display and/or CNC controller or the like. Such an additional display would then be in parallel to the first and second displays 37, 38. Alternatively, the displays 37, 38 and/or the keyboard 39 may be omitted from the measurement unit 3, and provided only on a remote station, to which the measurement unit is connected via the flying lead 41 and connector 40. However, in this event, it is important to note that signal processing is still carried out within the measurement unit 3 itself, by means of the signal processor 35. Thus, the signal provided at the connector 40 may be a standard TTL signal or the like, suitable for use with industry standard displays or controllers.

The power supply 33 may receive a primary power feed from the machine 4, or via the flying lead 41 and connector 40. The power supply 33 may comprise rechargeable batteries, such that it may be used without an external power feed.

In the cross-sectional diagrammatic view of Figure 3, there is shown the tube 21 containing balls 22. A plastics tube 311 surrounds the tube 21. The or each transmitting coil 312 is disposed around the plastics tube 311,

and the or each receiving coil 313 is disposed around the transmitting coil(s) 312.

As mentioned above, the balls 22 may be replaced by members of other shapes. By placing distinctively shaped members between the balls 22, the signal processor 35 may readily determine an absolute position between the reference means 2 and the measurement unit 3, since the different shapes of the members result in correspondingly different modulations, which can subsequently be discriminated. In addition to or as an alternative to members of different shapes to the balls 22, members may be provided of different magnetic materials. Alternatively, for example, inserts of non-magnetic material may be introduced between or adjacent balls 22, particularly to show zero positions at an end of the reference means 2.

The non-volatile memory 36 is provided to store a current position value, and retains that value when power is removed from the measurement unit 3. Where the measurement unit 3 is connected to a CNC machine or the like, then, upon restoration of power, the machine may be operated to make a small movement until the measurement unit 3 detects an absolute position on the reference means 2, possibly by means of one or more member of distinctive shape or material as mentioned above, and then returns to a current position, at which the measurement unit 3 can verify the current absolute position measurement value.

The elongate reference means 2 need not be rectilinear (although it often will be). In special applications, it could be curved.

In this specification, the verb "comprise" has its normal dictionary meaning, to denote non-exclusive inclusion. That is, use of the word "comprise" (or any of its derivatives) to include one feature or more, does not exclude the possibility of also including further features.

All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

The invention is not restricted to the details of the foregoing embodiment(s). The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed.

CLAIMS

1. A displacement detecting device comprising:
   a. an elongate reference means;
   b. a signal generator arranged to generate an electromagnetic signal;
   c. a transmitting means arranged to transmit said electromagnetic signal to said reference means;
   d. a receiving means arranged to receive said signal, the arrangement being such that displacement of said reference means relative to said transmitting and receiving means modulates said signal as received by said receiving means, such modulation providing information as to the amount of such displacement;
   e. signal processing means arranged to receive said signal from said receiving means and derive therefrom measurement information indicating the relative displacement of said reference means and body; and
   f. a common housing in which said signal generator, transmitting means, receiving means and signal processing means are mounted.

2. A displacement detecting device according to claim 1, wherein said measurement information is represented by a TTL quadrature signal that is output by said signal processing means.

3. A displacement detecting device according to claim 1 or 2, wherein said body provides a recess or aperture for mounting or passage of said

reference means to provide sliding movement between said body and said reference means.

4. A displacement detecting device according to claim 1, 2 or 3, wherein said reference means comprises at least one tube containing a plurality of spheres.

5. A displacement detecting device according to any of claims 1 to 4, wherein said transmitting and/or receiving means comprises a respective coil.

6. A displacement detecting device substantially as hereinbefore described with reference to Figure 1 or Figures 1 to 3 of the accompanying drawings.

7. A method of measuring the displacement of two parts relative to one another, comprising the steps of:

a. fitting to one of said parts the reference means of a displacement detecting device according to any of the preceding claims;

b. fitting to the other of said parts the transmitting and receiving means of the displacement detecting device;

c. transmitting said electromagnetic signal to said reference means by the transmitting means of the displacement detecting device as said parts are moved relative to one another;

d. receiving said signal by the receiving means of the displacement detecting device as said parts are moved relative to one another, with the displacement of said reference means relative to said transmitting and receiving means modulating said signal as received by said receiving means; and

e. processing the modulated signal received by said receiving means to derive from the modulation of the signal information as to the amount of the displacement of said reference means relative to said transmitting and receiving means and therefore the amount of the corresponding displacement of said two parts relative to one another.

8. A machine tool fitted with a displacement detecting device according to any of claims 1 to 6, or adapted to perform a method according to claim 7, in which the displacement detecting device is arranged to output a signal providing information as to the amount of relative displacement of two moving parts of the machine tool.

9. A machine tool according to claim 8, being a CNC machine.

The Patent Office

INVESTOR IN PEOPLE

Application No: GB 9824325.6 **Examiner:** Paul Jefferies
Claims searched: 1-9 **Date of search:** 16 February 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): G1N (ACNA, ACNC, ACND, ACNE, AEB, AEM, AFA)

Int Cl (Ed.6): G01B 7/14; G01D 5/20, 5/243

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2313199 A	(MITUTOYO CORPORATION) See figure 1.	1-3, 5, 7
X	GB 1513567	(NEWALL ENGINEERING) See figure 1 and page 2, lines 102-106.	1, 4, 5, 7
X	GB 0766656	(THOMSON-HOUSTON) See figure 5 and page 1, lines 45-59.	1, 5, 7, 8
X	EP 0676622 A1	(DAIMLER-BENZ AG) See Abstract and figures 3.	1, 5, 7-9
X	EP 0605847 A1	(MOTOROLA, INC.) See particularly page 8, lines 25-33 and figures 9 & 10.	1, 2, 5-7
X	WO 95/02807 A1	(ZACHO) See figure 2 and pages 7, first 2 paragraphs, page 12 final paragraph.	1, 5, 7
X	US 5619133	(SHANK et al.) See figure 9 and Abstract.	1, 5, 7
X	US 4862396	(NIRUMANDRAD) See figure 1 and Abstract.	1, 7, 8
X	US 4710709	(ANDERESON et al.) Column 3, lines 1-23 and figure 1.	1, 5, 7

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